RISK FACTORS AND CONTROL MEASURES DURING SLAUGHTER AND PROCESSING

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Measures concerning the production of microbiologically safe meat can be divided into those guided by the more or less classical, rigid "legislative" approach and a much more flexible "scientific" approach, e.g. the implementation of HACCP.

The protection of public health may be considered as one of the main objectives of meat inspection (Snijders and Berends, 1997). However, the methods and design of our Western European meat inspection originate from the beginning of this century, when it became clear that meat could play a role in the transmission of disease, and that consumers and commerce, needed some sort of safety and quality assurance. Since then meat inspection has comprised an inspection of each animal before and after it is slaughter. It is carried out by visual inspection, palpation and incision. On the grounds of what is found during meat inspection and/or what is already known by meat inspection authorities, laboratory examinations may be carried out (Berends et al., 1993).

Some inspection procedures, e.g. the incision of lymph nodes, can even have a negative effect on the safety and quality of meat, and there is a consensus of opinion that current meat inspection procedures are no longer adequate in protecting public health.

The development of Good Manufacturing Practices (GMP's) in the slaughtering and dressing phase, preferably coupled with total process control by means of the development of HACCP procedures, can contribute substantially to the safety and quality of meat, although they cannot entirely prevent carcass contamination.

Recent Directives demonstrate that the EU is now also convinced that the HACCP approach has the most potential. It comprised the following series of steps that must be taken to ensure that the entire process is suitably controlled.

1. Hazard analysis;
2. Identification of Critical Control Points;
3. Establishment of control criteria and critical limit values;
4. Monitoring of Critical Control Points (CCPs);
5. Corrective actions and Verification.

An important aspect of the HACCP system is to maintain records of monitoring procedures and corrective actions.

However, sometimes there are differences of opinion with regard to the location of CCP's and even about the hazards themselves. Therefore, a more objective approach to hazard analysis would be preferable.

A 'classical' means of assessing human health risks more objectively was developed originally for toxic and/or carcinogenic substances. In principle, the approach includes the following four steps (Berends et al., 1996):

1. Hazard Identification (also called Hazard Evaluation): the listing of all observed harmful effects of the agent in man or food animals.
2. Dose-response Characterisation (also called Dose-response Evaluation): the determination

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of quantitative relationships between doses and the observed effects.

3. Human Exposure Characterisation (also called Human Exposure Evaluation): the determination of the sources, routes, quantities and (active or inactive) chemical forms in which the agent reaches the target species.
4. Risk Characterisation (also called Hazard Characterisation): the combination of the three preceding steps, with the aim of assessing the probability that individuals will experience adverse health effects by the current level(s) and routes of exposure.

There are several reasons why quantitative risk assessment is not possible in the context of microbial food safety. For example, bacteria can multiply and die. Interactions between the many different bacterial species on meat and in the intestinal tract of man and food animals, coupled with the multifactorial nature of infectious diseases, further complicate matters. Our understanding of these processes is far from complete. Furthermore, reliable data on human exposure to meat-borne pathogens and subsequent development of disease in the community, are often scarce.

Quantitative assessment of microbiological risks from meat, and thus risk assessment-based safety assurance, is still in its infancy. Even so, it should be possible to incorporate some elements of quantitative risk assessment into HACCP. Thus, a promising approach is the construction of descriptive epidemiological models involving the entire food production chain. These can serve as a basis for the (semi-) quantitative assessment of risks and risk factors that need to be controlled.

Risks of contamination or infection can be quantified by means of prevalence or of incidence rates, and the influence of risk factors by means of odds ratios (OR) and attributable fractions. Furthermore, when exact quantifications appear to fail, the models are sufficiently detailed to be used in a hazard analysis critical control point (HACCP)-like approach and/or for the establishment of codes of good manufacturing practices (GMP) (Berends et al., 1996a).

With respect to the epidemiology of *Salmonella* spp. in pigs at the farm, and during transport and lairage at the slaughterhouse it was concluded that (Berends et al., 1996b):

i. about up to two thirds of Dutch pig farms appear to be more or less frequently infected, with mostly their own endemic 'house flora' of *Salmonella* spp.;
ii. the probability that pigs become infected on these positive farms at some time in their live is about 0.9;
iii. between 5-30% of these pigs will excrete the organism at the end of the fattening period;
iv. inadequate hygiene (odds ratio, OR, 39.7), the use of broad spectrum antibiotics (OR 5.6) and (re)contaminated feed (OR 1.6) play a major role in this situation;
v. within groups of positive pigs, animals are about four times more likely to become (re)infected with the *Salmonella* spp. from other herd members during transport and lairage (OR 4) than with *Salmonella* spp. originating from other herds (i.e. cross contamination);
vi. stress (OR 1.9) during transport and lairage plays an important role in the spread of, and the susceptibility for, infections.
vii. regarding the potential to act as major sources of carcass contamination, it is the digestive tract, its contents, and probably only the closely associated lymph nodes, such as the tonsils and mesenteric lymph nodes, that have practical relevance.

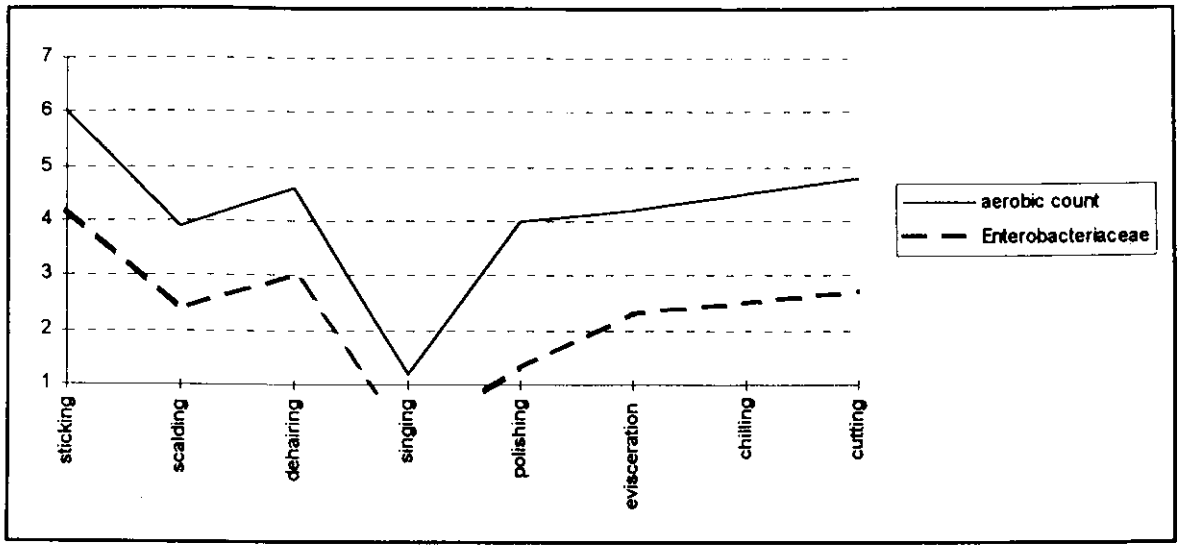

Fig. 1 Changes in colony forming units (log_{10})/cm^2 of aerobic flora and *Enterobacteriaceae* on the skin of pigs in Dutch slaughterlines (Gerats, 1990).

CONTAMINATION WITH ENTEROBACTERIACEAE

The changes in numbers of aerobic colony forming units (cfu) and cfu of *Enterobacteriaceae* per cm^2 carcass surface of pigs slaughtered in The Netherlands are presented in Fig. 1 (Gerats, 1990; Snijders, 1988). Steps that lead to an increase in *Enterobacteriaceae* counts are dehairing, polishing after singeing, and evisceration. Scalding and singeing are steps which result in a considerable decrease in numbers of microorganisms on carcass surfaces. Considering Fig. 1, it may be concluded that the surface is probably almost free of *Enterobacteriaceae* after singeing. The bacteriological condition of the polishing machines and the way evisceration, further dressing and meat inspection are performed determine the final contamination of the carcasses with *Enterobacteriaceae*.

Investigations of Gerats (1990) showed that under fairly normal slaughter conditions the average proportion of carcasses contaminated with *Enterobacteriaceae* above the detection limit of 1.3 log_{10} cfu/cm^2 increased from 4% after polishing to 40% after evisceration. The mean load of *Enterobacteriaceae* increased from 32 cfu/cm^2 after polishing to more than 100 cfu/cm^2 after evisceration. 'Dirty polishing equipment' is a risk factor in 'carcass contamination with *Enterobacteriaceae*' with an OR of 6.6. 'Faulty techniques and sloppy hygiene during evisceration', have an OR of 10.9. Evisceration can contribute up to 90% of the number of carcasses contaminated with *Enterobacteriaceae* as well as up to 90% of the load with these organisms. Another important observation was that meat inspectors did not work in a more hygienic manner than slaughterhouse personnel.

CONTAMINATION WITH SALMONELLA SPP.

The pig as a risk factor. The hygienic condition of walls, floors, ceilings, or, for that matter, human carriers present, are usually unimportant factors with respect to carcass contamination with *Salmonella* spp. in the slaughterline. Contamination via drips of condensed water and/or the air is also unimportant. This is substantiated by the fact that in most of the cases the *Salmonella* spp. found on the carcasses were only associated with animals slaughtered that day. The faeces of recently infected pigs may contain several thousands to several millions cfu *Salmonella* spp./gram. Faeces, tonsils and mesenteric lymph nodes of pigs at slaughter

weight, however, usually contain only up to about 10^2 cfu/g (Berends et al., 1996b).

The faeces is particularly important in relation to carcass contamination. Within batches, there is a strong correlation between the proportion of animals with *Salmonella* spp. in their faeces and the proportion of contaminated carcasses at the end of the line (Pearsons' coefficient 0.98; $P<.01$) (Berends et al., 1997; Chau et al., 1977). From data obtained by Brekelmans *et al.* (1980) it can be calculated that pigs with *Salmonella* spp. in their faeces are 3-4 times more likely to end up as a positive carcass than animals that are not carriers.

Furthermore, the attributable fraction of '*Salmonella* spp. in the faeces' can be estimated at approximately 70%. In other words, about 70% of all carcass contamination results from pigs themselves being carriers and about 30% because other pigs in the line were carriers (i.e. cross contamination) (Berends et al., 1997).

The process as a risk factor. It is obvious that the same process steps discussed earlier may also influence carcass contamination with *Salmonella* spp. Scalding and dehairing usually reduce the number of carcasses with *Salmonella* spp. on the skin with 50% (30-70%) (Chau et al., 1977; Sörqvist and Danielsson-Tham, 1990). Singeing reduces the number of *Salmonella*-positive carcasses with at least 97% (Kampelmacher et al., 1963).

Polishing after singeing plays a much less important role in the contamination of carcasses with *Salmonella* spp. than the evisceration and further processing. It is highly likely that polishing usually contributes only 5-15% to the total carcass contamination, and that the remaining 85-95% is the result of evisceration, dressing, splitting and meat inspection.

In order to achieve better control of contamination with *Salmonella* spp. current evisceration practices should be improved and slaughterhouse personnel and meat inspectors be briefed on the risks of these procedures.

Concerning meat inspection procedures, and the potential for (further) carcass contamination, it is recommended that the incision of lymph nodes, and frequent palpation of carcasses, should be replaced, as far as possible, by visual inspection. With respect to the design of GMP-protocols, it might be wise to consider that careful removal of especially the 'gut-associated' lymphoid tissues that may remain in the carcass, such as the lumbar aortic lymph nodes or the iliac lymph nodes, should reduce further the exposure of the consumer to *Salmonella* spp. via pork. For the same reason it is probably also wise to exclude the use of meat from the pig's head for the production of minced meat. Under practical conditions it will be very difficult to remove, for example, *Salmonella*-positive mandibular lymph nodes without damage.

CONTAMINATION WITH *LISTERIA MONOCYTOGENES*

The contamination of meat with *L. monocytogenes* has mostly another origin.

Although faeces and skin of slaughter pigs are sometimes considered to be sources of *L. monocytogenes* contamination, the slaughterhouse environment has been implicated as an important source. Van den Elzen and Snijders (1993) compared the incidence of *L. monocytogenes* at earlier stages of slaughtering with the cutting room environment and primal cuts. Only 2-7% of the carcasses and 0-10% of the environmental samples in the 'clean' part of the pork slaughterline were found to be positive for *L. monocytogenes*. In the cutting room 11-36% of the primal cuts and 71-100% of the environmental samples were found positive.

Results of a second investigation using randomly amplified polymorphic DNA (RAPD) Van den Elzen et al. (1995) showed that it is tempting to assume that *L. monocytogenes* strains originating from pigs do not account for the contamination of the primal cuts. *L. monocytogenes* was most frequently isolated from conveyor belts (71% of inner surfaces and

35% of working surfaces), rotating tables (30%) and cutting boards (22%) before production had begun (Keuzenkamp et al., 1997). With the RAPD typing method it was possible to prove that the cutting rooms in three different abattoirs have its own specific house flora.

These findings indicate that the contamination of meat with *L. monocytogenes* is from another origin as the *Salmonellae* contamination.

Excellent cleaning and disinfection procedures in combination with better design of cutting rooms as well as construction of machinery, can reduce the contamination cycles of *L. monocytogenes*. Producers of processing equipment and those who buy machines should take into account the consequences of the design of equipment for the hygienic quality of meat more than they currently appear to do.

DISCUSSION

Regarding *Salmonella* spp., the primary production phase has to work towards a substantial reduction in the number of finishing pigs that carry this pathogen. The best and most permanent solution will be to produce *Salmonella*-free pigs.

However, the *Salmonella* problem on farms is unlikely to be dealt with effectively on the short term. Nationwide *Salmonella* and control programs as applied in Denmark (Nielsen et al., 1997) are prerequisites for tackling this problem.

With respect to the application of the HACCP approach in slaughterlines, it may be tempting to conclude that (1) singeing is a critical control point (CCP) regarding the elimination of risks from `skin-positive' (live) animals; (2) evisceration is a CCP regarding the contamination of carcasses with faeces-borne *Salmonella* spp.; (3) the incision of lymph nodes as carried out by meat inspectors is a CCP regarding the contamination of carcasses with lymph node-borne *Salmonella* spp. However, when the HACCP-concept is applied in its strictest sense, it should be concluded that both the slaughterline as a whole and the incoming pigs, are the critical control points, because there are no steps in the process which have been designed intentionally to reduce the hazards.

It is recommended that EU regulations be changed in such a way that they allow for decontamination of carcasses with a 'safe' substance, for example lactic acid (Berends and Snijders, 1985).

To ensure that this procedure will not lead to a slackening in the hygiene standards, the use of codes of Good Manufacturing Practices should be a prerequisite.

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